Volume 1, Number 1
ISSN: 0884-1012

$3.00 in United States
$3.75 in Canada and Mexico

Robot Experimenter™

A Voice-Controlled Robot System

U.S. POSTAGE
PAID
BULK RATE
PERMIT #1
PETERBOROUGH
NH

W.M. Richman
B&B Enterprises
Hill-Top Heights
N. Platte, NE 69101

SAMPLE

Welcome to Robot Experimenter

Raymond GA Cote, Editor/Publisher

Hello, and welcome to Robot Experimenter, a monthly publication that shows you how to design, build, and most importantly use various personal and educational robot systems.

Personal robots are on the brink of discovery. We are just learning how they can be used and how they can make our lives a little easier.

One of our goals at Robot Experimenter is to show you how to design, construct, and, most importantly, use personal robots.

Another goal is to tone down and explain some of the emotional terms that are so easily bandied about the industry. One such term is "personal robot."

What is a personal robot? Does it do the dishes, wax the floor, clean the windows, or fetch your slippers? For some reason, many people believe that the term personal implies that the robot is used in the household. I had hoped we would have learned our lesson from so-called "personal" computers.

The term personal indicates that the item in question belongs to a single person. Just as there is a one-to-one correlation between a person and the computer on her desk, so can we consider a one-to-one relation between a person and her robot.

Although a personal robot may not be used for household chores (at least for some time), it should still be useful. Today, the best use to which these robots can be put is education. Personal robots today teach us how to integrate electronic, computer, mechanical, mathematical, and programming skills into a final end product. They teach us about real-time programming, navigation, sensor systems, and open our eyes to the complex world in which we live.

Perhaps more important than using robots to teach robotics, is our ability to use robots to teach us about other topics. Once you've spent time in a classroom full of children commanding robot to draw patterns on the floor, move blocks around, and map a room, you realize that a primary use of personal robots is to teach people how to solve problems.

Robots provide a useful problem-solving tool. They can help teach people, and particularly children, how to think through a problem, attack it logically, and, when the proposed solution doesn't function as expected, how to backtrack and isolate the difficulty.

Thus we come to the reason for choosing Robot Experimenter as our magazine title. To survive and fully enjoy today's complex, technological society, we all need to be experimenters: trying new ideas, testing new tools, and finding uses for old, established techniques. Everyone who builds and uses personal robots is an experimenter because the field is so new that there are yet to be any rules. The world is opening up before us and we intend to answer tomorrow's challenge.

Come, join us in our exploration of wonder.

Raymond GA Coté

Robot Experimenter

Editor/Publisher
Raymond GA Cote

Consulting Editors
Walter Glod
Heath Robots

Russ Eberhart
Robots and Disabled Persons

Niki Delgado
Robots and Education

Production Work
Alpaugh Enterprises

Typesetting
debset

Photography
Deborah Porter

Printing
Travers Printing, Inc.

Advertising Manager
Elizabeth S. Alpaugh-Cote

Cover Art: The cover shows Russell using his voice controlled robot/computer workstation lifting a glass for him to drink. Russell has been developing applications that allows physically disabled people to use the available computer resources to compliment their lives. This is just one use for a voice controlled workstation.

Table of Contents

Robot Experimenter (ISSN 0884-1012) is published monthly by CEARGS. Executive, editorial, circulation, and advertising offices: 174 Concord St., Suite 31, Peterborough, NH 03458, telephone (603) 924-3843. Address subscriptions to **Robot Experimenter**, PO Box 458, Peterborough, NH 03458-0458.
Postmaster: send address changes, USPS Form 3579, undeliverable copies, and fulfillment questions to **Robot Experimenter**, PO Box 458, Peterborough, NH 03458-0458. Third class postage paid at Peterborough, NH 03458 and additional mailing offices. Subscriptions are $24.00 for one year in the USA and its possessions. Subscriptions are $28.00 for one year in Canada and Mexico. Foreign subscriptions and sales should be remitted in United States funds drawn on a U.S. bank. Please allow six to eight weeks for delivery of first issue. Printed in the United States of America.
Address all editorial correspondence to the Editor, **Robot Experimenter**, PO Box 458, Peterborough, NH 03458-0458. Unacceptable manuscripts will be returned if accompanied by sufficient first-class postage. Not responsible for manuscripts or photos. Opinions expressed by the authors are not necessarily those of **Robot Experimenter**.

Subscription questions or problems should be addressed to: **Robot Experimenter** Subscriber Service, PO Box 458, Peterborough, NH 03458-0458.

A Voice-Activated Robot/ Computing Workstation

Russell C. Eberhart, Ph.D.
10293 Wilde Lake Terrace
Columbia, MD 21044

This article describes the development of a system that combines an IBM PC with a robot arm into an integrated robot/computing workstation. What makes the system unique is that it can be placed entirely from voice control. One of the things that makes the development interesting is that it was put together more or less by accident.

I teach an evening class in robot for Howard Community College in Columbia, Maryland. I had borrowed a Scorbot ER-III robot arm for evaluation purposes, and, as a class project one evening, we got the arm up and running using an Apple IIe as the host computer.

Later the same evening, after the class had gone home, I decided to connect the arm to an IBM PC, since the software for both Apple and IBM is provided with the robot arm. It turned out to be straightforward to get the arm operational on the PC. Indeed, although it isn't the purpose of this article to review the Scorbot arm, I will say that I am quite impressed with the Scorbase software, and that the arm seems to perform as specified by the company.

Photo 1: Experimental workstation layout.

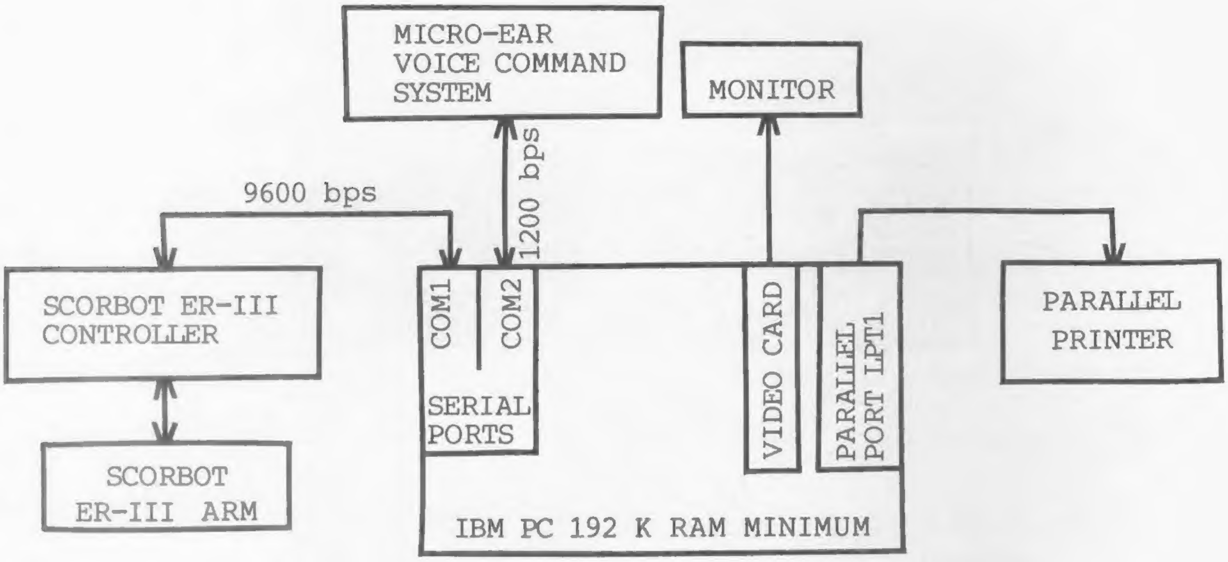


Figure 1: Block diagram of the Micro-Ear/IBM PC/ScorBot ER-III Workstation.

Photo 2: The Scorbot ER-III can be used to manipulate objects in the environment. Here it is using a BSR controller to turn on a radio.

After putting the arm through its paces on the IBM PC, I leaned back in my chair and looked around the room. There, on my shelf, sat an Arctec Micro-Ear Voice Command System. I said to myself, "I wonder if the arm, the ear, and the PC would all work together..." By dawn the answer was clearly, "Yes."

This article describes how the workstation components work together, the software that acts as the "glue" for the system, and some possibilities for extending the work into additional system configurations and applications.

SYSTEM DESCRIPTION

The system described here is termed a workstation in general accordance with the terminology evolving from the National Bureau of Standards (NBS) Automated Manufacturing Research Facility (AMRF) project (reference 1). A typical workstation consists of one robot arm, and includes a small integrated group of equipment.
While the NBS is involved primarily with large-scale manufacturing facilities, and you and I are probably more involved with robots

at an experimental and/or educational level, it seems to me that a consistent terminology is important to establish as early on as possible in a new technology. So, I resisted the temptation to call the combination robot/computer system a roputer or a combot.

Figure 1 shows a block diagram of the workstation. The IBM PC I use has 256 Kbytes of programmable memory and two double-sided/double-density (DSDD) diskette drives. A minimum configuration would be one DSDD drive and 192 Kbytes of memory. (The192 Kbytes is a system requirement for the Scorbot arm software.)

The IBM PC used here also contains a Quadram board with two asynchronous serial ports configured as COM1 and COM2 for communicating with the Scorbot arm and the Micro-Ear voice recognition system. Another Quadram board with a parallel port is used to talk to an Okidata 92 parallel printer with graphics. The video display board is an old Columbia Data Products video board I had lying around. Any of the popular communication or display boards should work with the software described here.

The robot arm is a Scorbot ER-III, manufactured by Eshed Robotec, Ltd., Tel-Aviv, Israel. It has five axes of freedom plus gripper open and close, a two-foot reach, and a rated load capacity of about 2.2 pounds. The arm seems aimed mainly into the educational and advanced personal robot markets, and lists for $4,200.

The Scorbot controller unit features an Intel 8031 microprocessor with Scorbase software that provides interactive programming at three levels. Programs of up to 400 lines can be stored for later execution.

The voice recognition system is a Micro-Ear Voice Command System from Arctec Systems, Inc., Columbia, Maryland. The system has a 256-word vocabulary, divided into eight groups of 32 words each, and has battery-backed CMOS programmable memory, so that training is retained even when power to the unit is turned off.

As is the case with all speech recognition unit currently available for under $5,000, the unit is speaker-specific. However, you can upload and download training to and from diskette with a single keystroke from the training program. Therefore, changing users and/or applications is relatively easy. The Micro-Ear is described in more detail in "Voice Command for Your Personal Computer" (reference 2). The cost of the system, with the EAR-DOS software that allows

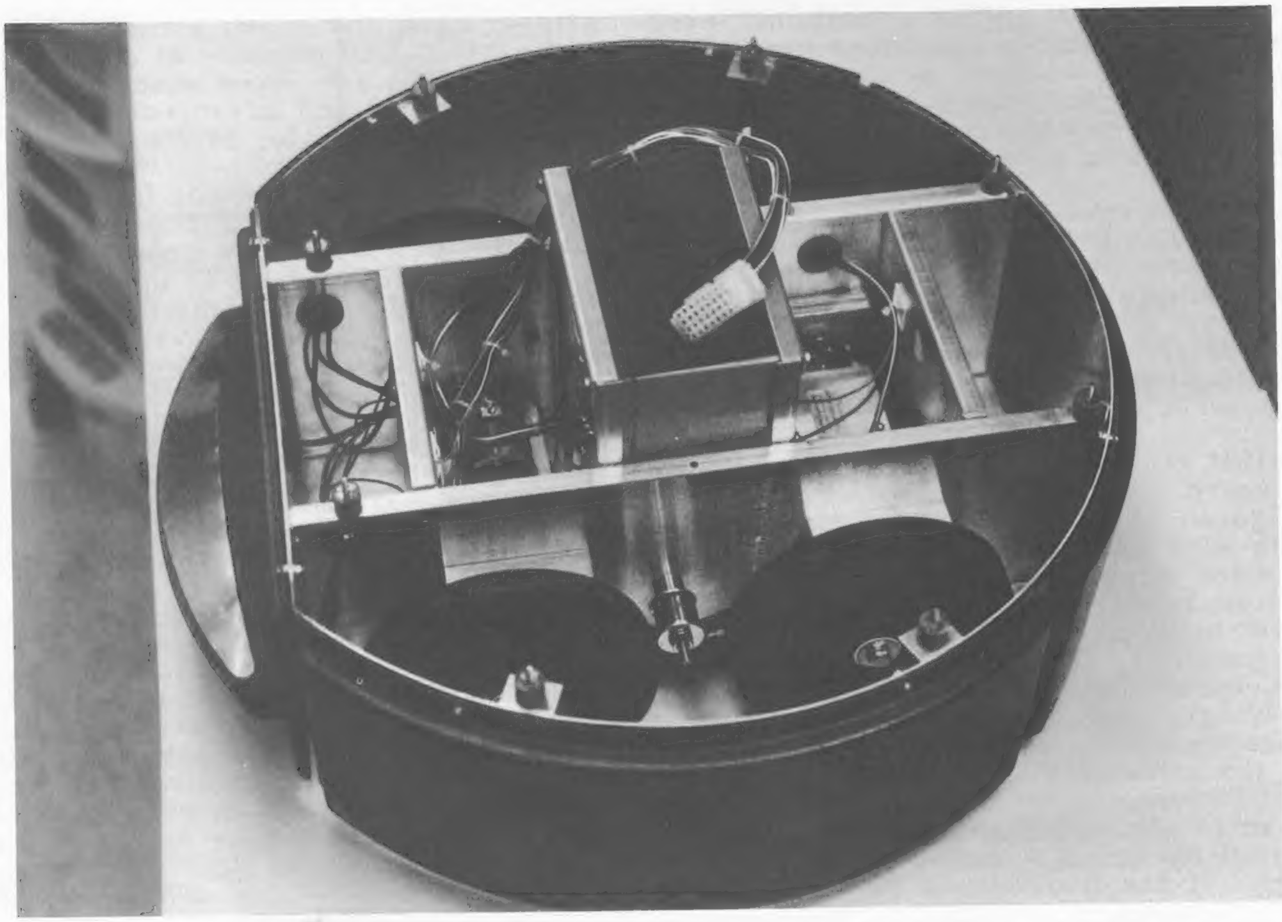


Photo 3: The Gemini robot base. The Scorbot ER-III arm will eventually be mounted on this base to create a mobile, voice controlled robot system.

you to have concurrent voice/keyboard input inside virtually any applications software, is $649.

A new, expanded, version of utility software, named ROBO-DOS, is currently being developed. This software is designed to facilitate the use of the Scorbot arm and IBM PC as an integrated system. Cost of the Micro-Ear with ROBO-DOS will be about $895.

Connecting the Scorbot arm and Micro-Ear speech recognition system to the IBM PC consists of following the wiring diagrams in the respective manuals to connect the systems to the IBM PC serial ports. Serial communications with the Scorbot controller is at 9600 bits per second (bps); with the Micro-Ear at 1200 bps.

Photo 1 shows the development workstation. The Scorbot controller unit is located just to the right of the arm. The Micro-Ear is on top of the PC, just under the monitor. A headset microphone is lying on the PC, to the right of the Micro-Ear.

WHAT DOES IT DO?

As is the case with almost every robot-related system ever conceived, the first question people generally ask about the workstation is, "What does it do?" One rather oversimplified way of stating what it does is to say that it lets you use the full capabilities of the computer and the arm with concurrent voice/keyboard input. That is to say, you can use either form of input, or alternate, character by character, back and forth between voice and keyboard input.

However, perhaps the most powerful capability is that, once the equipment is powered on, you can program and run both the computer and the arm totally by voice, with no need for the keyboard. For example, a disabled person with no use of his or her hands can power the system up with a standard air ("sip and puff") switch, and from then on have the workstation totally under voice control.

As far as I can tell, you can run any applications software written for the PC using the voice control station. I have tried a number of packages, including: Word Perfect, Lotus 123, Visicalc, and PC-File III. In the future, I will be testing several graphics packages. The ability to produce high-quality graphics under voice control has particular attractions for disabled applications, both for work-related and therapeutic reasons.

You can also access the arm, move it about, write programs for it, and save, load, and execute those programs totally under voice control. This month's cover photo shows the arm being used to to lift a cup up in front of my face and let me drink from a straw. The program is set to hold the cup up for 20 seconds and then set it down again. I can keep the cup up for longer periods by simply giving a verbal command while the cup is elevated, and issuing another command when I'm ready for the cup to be returned to the table.

Note that I am using a headset microphone. This unit is a Shur 3M 10db noise cancelling microphone. Depending on the particular Micro-Ear configuration, it is either provided with the Shure unit or with a Radio Shack Highball 2 mike. You will probably want the noise cancelling unit if you expect to be in noisy environments, or if you want to move your head around a lot while using the workstation.

Another use of the workstation is for environmental control using off-the-shelf BSR control components. Photo 2 shows the robot arm turning on a radio by pressing the appropriate button on a standard BSR control unit. The verbal command "switch on radio" causes the arm to pick up the pointer, move over to the BSR control unit, press the correct switch for about one second, and replace the pointer in the container. The radio is plugged into a BSR lamp module set to the correct house and device codes.

You could use the same type of routine to have the robot dial a push-button telephone. A command such as, "pick up phone" would cause the robot to take the receiver off the hook and place it on the table. The robot would then wait for you to speak the number to be dialed. After dialing the number, the robot would pick-up the receiver and hold it up to your ear.

Of course, both these applications assume that the BSR controller and the telephone are in precisely known locations. This is still a rather unintelligent system and will happily punch nonexistent buttons in empty space. However, through voice control you can easily manipulate all the robot's functions and move it slowly left, right, up, and down, until it reaches the spot you want. The important point to remember is that this is a workstation and acts as a starting point for future applications.

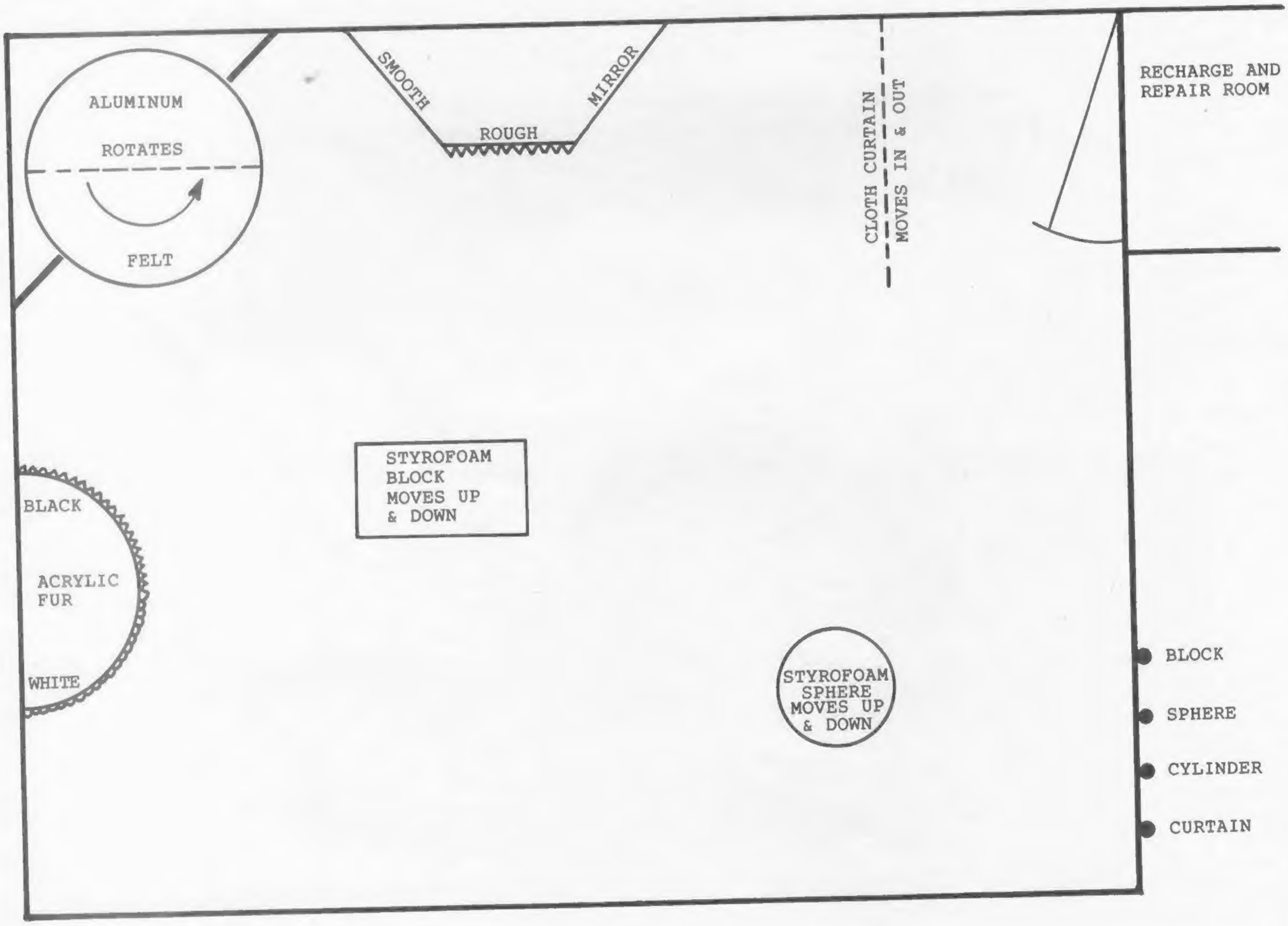
Robot Habitat

Jake Mendelssohn
The Science Museum of Connecticut
950 Trout Brook Drive
West Hartford, CT 06119

Robots, robots, everywhere, but not a one to see.

The Robot Revolution is upon us. Wherever we turn, we see, hear, and read about robots--what they can do and how they are going to change our lives. Many universities and large corporations are conducting huge research projects involving robots and some schools around the country are offering basic courses in the field. But where can the average adult or child go to see robots perform, to learn how they work, and to see them interacting with their environment?

Giving people a sense of what robots are, what they can do, and their strengths and weaknesses is the goal of the Robot Habitat Exhibit. It will be a place where the public can watch robots in action; where they will be able to perform simple experiments with the robots to see how they react; where they can learn about robots and their advantages and disadvantages in various situations.



This exhibit will provide sheer enjoyment as well as an invaluable educational experience. It will afford the unique opportunity to observe robots interacting and the problems they, and their designers, face in the real world.

DESCRIPTION

The Habitat described here has been designed as an exhibit at the Science Museum of Connecticut in West Hartford. Bob Content, Science Museum Director, originally conceived of the idea as the logical extension of a normal zoo. "People at a zoo can only watch the animals living in their cages. The Robot Habitat will allow people to interact with the 'creatures' on exhibit and learn how the robots deal with their environment."

The Habitat will support four robots operating independently in a 19 by 15 foot area. The Habitat will contain several objects of varying shapes and covered with a variety of materials. Each robot will use a different type of sensor (sonar, touch, infrared, and radar) to "feel" its way around the Habitat.

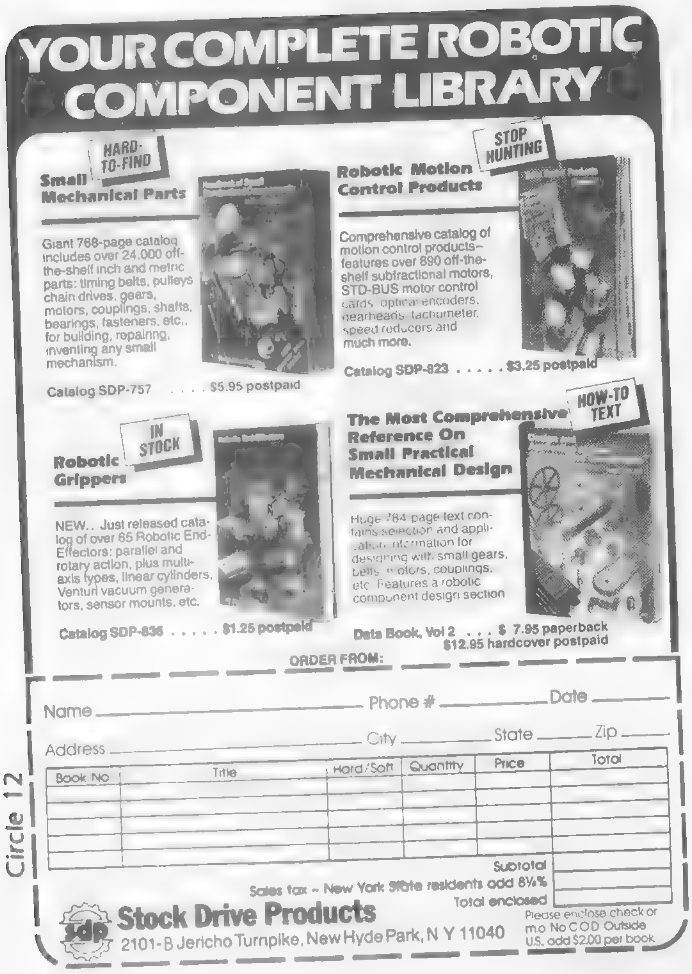
The audience, watching from outside the Habitat, will try to determine what type of sensor each robot has and the relative advantages and disadvantages of each. Their decisions will be based on the robot's reaction when it encounters different types of barriers.

The audience can change the Habitat environment by pressing buttons on the outside of the exhibit. For example, a cylinder with felt (sound absorbing) on one side and sheet metal (sound reflecting) on the other could be rotated to expose the alternate sides in order to test the different sensors against the two materials. Styrofoam blocks (radar absorbing and invisible to heat sensors) can also positioned around the Habitat, or lifted up out of the robot's way.

Figure 1 shows how a variety of varying obstacles might be arranged througout the Habitat. The purpose is to supply a variety of materials to the various sensors, some of which are "visible" to the particular sensor and others that are "invisible."

ROBOT SPECIFICATIONS

The robots are typical "trash can" models, cylindrical, 3-1/2 feet high and 18 inches in diameter. The bodies are made of high-density Duramold and individually painted with bright, identifying colors. A dome on top of each body allows visitors to view the operating electronics within each robot. Since the purpose of this exhibit is to demonstrate how robots use their sensors to interact with the world, none of the robots will have arms.



Circle 12

The robot base consists of two drive wheels and two idler wheels. Each robot is assigned their own sensor (sonar, infrared, touch, etc.). When a robot senses an object in its path, it turns to avoid the object and continues to wander around the Habitat.

A maintenance area is attached to the Habitat. This area, which is part of the exhibit, provides facilities for recharging and repairing the robots.

CONCLUSION

The Habitat is an experiment in people-robot interaction. It is intended to demonstrate how a robot deals with various changing factors in its environment.

Perhaps most importantly, it presents robots in a realistic setting. People will learn about a robot's limitations; for example, the inability to sense heavy drapery using only an ultrasonic transducer. By presenting these robots in a practical setting, people will come to understand how robots deal with their environment and come to view robots not as something magical, but as just the latest in mankind's efforts to build more useful tools.

About the Author: Until recently, Jake Mendelssohn was president of Nationwide Robots, a promotional robot manufacturer. Jake now consults to The Science Museum of Connecticut and is responsible for the design and development of the Robot Habitat.

Classifieds

Inexpensive Robot Computer Control using Sinclair and Timex-Sinclair computers. Expansion and high-speed I/O circuit boards used in "H.E.N.R.Y," the personal robot winner of a Golden Droid Award at the first International Personal Robot Congress & Exposition. Buffered Buss Expansion Board, with seven expansion points. For ZX81, TS1000, or TS1500. Bare Board with documentation $40.00. Input/Output Board, with machine code control of eight parallel I/O lines. For ZX81, TS1000, TS1500, or TS2068. Bare Board with documentation $10.00 or two for $18.00. Prices postpaid to U.S. and Canada. Kits of above circuits also available. Write for information & prices. BUDGET ROBOTICS & COMPUTING, Box 18616, Tucson, AZ 85731.

Personal/Educational robots, turtles, kits, and books at discount prices. Write or call Cal-Robot, 16200 Ventura Blvd., Suite #223, Encino, CA 91436, (818)905-0721.

DEVELOPERS WANTED. Earn income by designing and developing prototype robot-related systems for areas in which you have special expertise. Write immediately to Intelligent Machines Corp., 1019 8th St., Suite 302, Golden, CO 80401.

ROBOT CATALOG. $2.00 Refundable. Complete line of Personal Robots, Robot Kits, Toys, Books, and Peripherals. The Robot Store, 906 Bancroft Way, Berkeley, CA 94710.

HEROically Speaking

Walter Glod, Jr., President
HERO Resource Exchange
10802 Condrey Ridge Court
Richmond, VA 23236

One day a friend asked me what my HERO robot did. "Nothing really," I replied, "but I've learned a lot from it." He blinked a few times and then changed the subject. I knew that what he was asking was what type of practical chores this personal robot has done for me. Although HERO is not capable of carrying on household dudties such as washing the windows or preparing dinner, he has been an incredible learning tool. I often refer to this robot as a laboratory on wheels. I can experiment with stepper motor control, sensors, artificial intelligence, voice synthesis, sonar navigation, and microprocessor interfacing and programming all in one mobile package.

Also in the last two years as president of the HERO Resource Exchange, I have learned that others are constantly doing interesting things with HERO. Members have written to me describing projects such as floor tape navigation, simple sound recognition, home security, plant watering, parrot feeding, phone answering, store promotions, childrens games, party butler, etc. ... all done with HERO. As more and more of these robots fall into the hands of creative people, who knows what things people will dream up for it to do? One advantage of a "store bought" robot is that, like personal computers, others can share and benefit from programs and ideas that come from a standardized system.

HERO IN THE DARK?

One way to keep HERO inactive when you turn-in for the night is to automatically put him to sleep as well, automatically. By using the following subroutine in your program, you can shut down a looping program by simply turning off the lights in the room. This routine only works if your program is one that loops over and over. When the robot senses darkness he will say "Wow It is Dark!" and turn off the display until you either turn on a light or the morning sun enters the room. HERO will then say "I See Light." and resume the program.

The following routine is a looping program to demonstrate the Good Night subroutine. The example prints HELLO on the display until HERO senses darkness; at which point the Good Night subroutine takes effect. Substitute your own looping program for the HELLO demo program. The subroutine can be relocated anywhere.

DEMO HELLO PROGRAM

```
0300    BD F6 5B BD F7 E5 37 4F 0E 0E
        7E A0 BD 04 00
```

GOOD NIGHT SUBROUTINE

```
0400    41 B6 C2 40 81 01 24 13 72 FB 45
        BD F6 5B 41 B6 C2 40 81 05 22 02
        20 F7 72 FB 37 39
```

RANDOM SMARTS?

BASIC has a handy command that can give HERO a sense of unpredictable intelligence. Use the HERO BASIC RND command to direct the robot to perform a task randomly. Although you could use the command in some fashion to randomly control motors, sensors, or even operation times of the robot, the following example uses RND to control what statements HERO speaks.

The example uses phrases that are in the robots read-only memory (ROM). You must convert the hexadecimal addresses of your own statements to decimal if you wish to add some of your own phrases in memory. Since the RND function returns a number from 0 to 99, lines 20, 30, and 40 correct the number to within the number of phrases in your DATA statement.

```
1    Z = 1
5    DATA 64075,64363,64342,64379,64449,
     64603, 64669, 64709,64838
10   X = RND
20   IF X <10  THEN GOTO 50
30   X = X / 9
40   GOTO 20
50   FOR I = 1 TO 9
60   READ H
70   IF Z = X THEN SPEAK H
80   Z = Z + 1
90   NEXT I
100  GOTO 1
```

For more information about the HERO Resource Exchange, send me a self-addressed, stamped envelope.

PLACE
CORRECT
POSTAGE
HERE

Robot Experimenter
P.O. Box 458
Peterborough, N.H. 03458-9958

Robot Experimenter
PO Box 458
Peterborough, NH 03458

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY CARD
FIRST CLASS PERMIT NO 58 PETERBOROUGH, N.H

POSTAGE WILL BE PAID BY ADDRESSEE

Robot Experimenter
P.O. Box 458
Peterborough, N.H. 03458-9958

Robot Experimenter
PO Box 458
Peterborough, NH 03458

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY CARD
FIRST CLASS PERMIT NO. 58 PETERBOROUGH, N.H

POSTAGE WILL BE PAID BY ADDRESSEE

Robot Experimenter
P.O. Box 458
Peterborough, N.H. 03458-9958

Many **Robot Experimenter** advertisers allow you to receive free product information simply by circling the appropriate response number. Circle the appropriate number, and then mail this card back to **Robot Experimenter**. Their latest information will soon be on its way back to you.

READER SERVICE

Reader Service Number	Company	Page Number
3	Amarobot	11
1	Amsi	5
6	Arctec	CIII
9	Basicon	7
11	BerSearch	23
19	Interface Tech.	23
4	Mouser	14
10	NorthWest Comp.	13
20	NorthWest Comp.	23
2	Parsec	9
8	RIA	3
5	Rio Grande	14
7	Spectron	9
12	Stock Drive Prod.	10

Your answers are appreciated.

1) Do you own a commercially-available personal/ educational robot? . . . . Yes/No

1b) If yes, what type? ____________

2) Have you built your own robot system? . . . . Yes/No

3) Do you plan to obtain a robot in the near future? . . . . Yes/No

4) Check the appropriate boxes. I am an:

☐Electrical Engineer ☐Mechanical Engineer
☐Computer Engineer ☐University Professor
☐Vo-Tech Professor ☐Other Educator
☐Experimenter ☐Other: ________

Name: ____________

Title: ____________

Company: ____________

Address: ____________

City/State/Zip: ____________

Telephone: ____________

Robot Experimenter
P.O. Box 458
Peterborough, NH 03458
603/924-3843

Name ____________
Title ____________
Company ____________
Address ____________
City ____________
State ________ Zip/Country ________
Charge my ☐MasterCard ☐VISA
Account No. ____________
Expires ____________
Signature ____________

Payment Enclosed

☐12 issues $24

☐24 issues $40

Canada & Mexico

(Please include payment in U.S. dollars drawn on a U.S. bank)

☐12 issues $28

☐24 issues $50

Robot Experimenter
P.O. Box 458
Peterborough, NH 03458
603/924-3843

Name ____________
Title ____________
Company ____________
Address ____________
City ____________
State ________ Zip/Country ________
Charge my ☐MasterCard ☐VISA
Account No. ____________
Expires ____________
Signature ____________

Payment Enclosed

☐12 issues $24

☐24 issues $40

Canada & Mexico

(Please include payment in U.S. dollars drawn on a U.S. bank)

☐12 issues $28

☐24 issues $50

Robot Experimenter™

For Robot Developers

Robot Experimenter satisfies your thirst for personal robot design information.

Robot Experimenter is a new publication devoted to the design, construction, maintenance, and use of personal, experimental, and educational robots.

Robot Experimenter provides more than just an overview of today's personal robot technology. Each monthly issue is filled with in-depth, detailed robot design and construction information, including full diagrams and program code.

Robot Experimenter also provides innovative robot applications and shows how you can use the latest AI programming techniques to increase your robot's IQ.

The premier monthly issue of **Robot Experimenter** debuts in September. Use the tear-off card below to ensure you don't miss a single issue.

Subscriptions received before 1 October 1985 will be charged only $18. That's 50% off the newstand price and 25% less than the normal $24 subscription price.

Subscribe today and **Robot Experimenter** will help you develop tomorrow's personnel robots.

Robot Experimenter is published monthly by CEARGS, 174 Concord St., Suite 31, Peterborough, NH 03458, phone 603/924-3843. For more information, contact Raymond GA Cote or Elizabeth S. Alpaugh-Cote.

Robot Experimenter
P.O. Box 458
Peterborough, NH 03458

NAME ____________________

TLE ____________________

COMPANY ____________________

DRESS ____________________

____

TE ________ ZIP/COUNTRY ________

my ☐ MasterCard ☐ VISA

Payment Enclosed

☐12 issues $18 if postmarked before 1 October 1985

☐12 issues $24 if postmarked after 1 October 1985

Canada & Mexico (Please include payment in US dollars drawn on a US bank)

☐12 issues $22 if postmarked before 1 October 1985

☐12 issues $28 if postmarked after 1 October 1985

ACCOUNT NO. ____________________

EXPIRES ____________________

SIGNATURE ____________________

Events

Sept. 6-8, 1985. 2nd Personal Robot Congress. San Francisco, CA.
A conference designed to gather people interested in the design and application of personal robot technology. This year's theme is "Personal Robots: Fantasy Taking Form." The show is sponsored by the National Personal Robot Association and Robotic Industries Association. Manufacturers will display the newest personal robot systems. An informative technical conference accompanies the exhibits.
Contact: Jeff Burnstein, RIA, PO Box 1366, Dearborn, MI 48121, 313/271-7800.

Sept. 9-10, 1985. Second International Conference on Advanced Robotics. Tokyo, Japan.
This conference provides an international forum for exchanging information on intelligent, mobile, and sensory robot systems. Approximately 70 papers will be presented.
Contact: Mr. A. Yasutake, Organizing Secretary, Japan Industrial Robot Association, Kikai Shinko Kaikan Bldg., 3-5-8, Shibakoen, Minato-ku, Tokyo, 105 JAPAN.

Sept. 21-22. Annual Forth Convention. Palo Alto, CA.
This convention focuses on current developments and uses of the Forth computer language and offers exhibits, hands-on tutorials, lectures, and seminars.
Contact: FIG, PO Box 8231, San Jose, CA 95155, 408/277-0668.

Sept. 23-25. Space Tech '85. Anaheim, CA.
Space Tech '85, sponsored by nine technical and engineering societies, focuses on the engineering technologies and solutions required to make space industrialization practical and economical. Sessions cover: artificial intelligence, robotics, guidance, controls, sensors, materials processing, simulations, software, structures, habitats, propulsion, and space manufacturing.
Contact: Gregg Balko, Technical Activities Dept., SME, One SME Dr., PO Box 930, Dearborn, MI 48121, 313/271-1500x368.

Oct. 9-11, 1985. Robots East. Boston, MA.
This second regional industrial robot show sponsored by the Robotic Industries Association (RIA) will be held at the Bayside Exposition Center in Boston. Robots East features product demonstrations by leading robot manufacturers and accessory equipment suppliers. A comprehensive technical conference accompanies the exposition.
Contact: Jeff Burnstein, Robotic Industries Association, PO Box 1366, Dearborn, MI 48121, 313/271-7800.

Nov. 4-7, 1985. SENSORS '85. Detroit, MI.
Running concurrently with AUTOFACT '85, SENSORS '85 focuses on three areas: robotic sensors, machine tool handling, and dimensional inspection. Technical sessions on both research/theory and applications will be offered.
Contact: Tom Akas, SME, One SME Drive, PO Box 930, Dearborn, MI 48121, 313/271-1500.

March 3-6, 1986. Agri-Mation 2. Chicago, IL.
Cosponsored by the American Society of Agricultural Engineers (ASEA) and the Society of Manufacturing Engineers (SME), Agri-Mation 2 is a conference and exposition focusing on automated systems and components for agriculture and the food processing industry. The conference discusses advanced automation technology such as computer-integrated systems, robotics, sensors, and electronics.
Contact: Dave Visscher, Technical Activities Dept., SME, One SME Dr., PO Box 930, Dearborn, MI 48121, 313/271-1500, x379.

Meet NPRA

The National Personal Robot Association (NPRA) is a new trade group formed to promote the personal robotics industry. A cosponsor of this year's International Personal Robot Congress (IPRC), NPRA was born in August, 1984 following the first IPRC held in Albuquerque, NM. The industry's first major gathering, IPRC '84 proved that an organizational "home" was needed for companies and individuals interested in personal robot.

Members of the IPRC'84 steering committee met with officials of Robotic Industries Association (RIA) to create NPRA. Though managed by RIA, a 330 member company trade group, NPRA has its own Board of Directors *and establishes its own plans and priorities.*

The first priority was assuring the continued growth of IPRC. The next priority was establishing a stronger membership base of individuals and companies. Dues were structured to be affordable, with corporations paying $300, individuals $30, and full-time students just $10 annually. Membership is expected to top 400 following IPRC'85.

NPRA plans to collect and report industry statistics, publish and distribute books and films, hold seminars on topics of interest to the membership, and serve as the focal point of information about the personal robotics industry.

Current NPRA Board of Directors include: Joseph Bosworth (Chair) of Robot Sciences Corp., Douglas Bonham of Heath Company, Russell Eberhart (formerly of Arctec Systems, Inc.), Mike Forino of United States Robots, Dave Gossman of Iowa Precision Robotics, John Peers of Novix, Nelson Winkless of ABQ Communications, and Don Vincent of Robotic Industries *Association.*

For more information about NPRA, contact the headquarters office at PO Box 1366, Dearborn, MI 48121, telephone 313/271-7800.

If you are designing and building a mobile robot, or if you are planning to do so, then you know how important it is to carefully select an appropriate main computer.

The computer must have lots of bit-level I/O (input/output), a large memory, computational speed, and at the same time consume very little power. While you're at it, throw in a real-time clock, analog to digital (A/D) converter, numerous communications ports for controlling auxiliary computers, and an expansion capability just in case you want to add on a few things later. Oh yes, don't forget about software. You'll need routines for entering machine code, disassembling code, performing analog to digital conversion, displaying text, handling keyboard input, reading and setting the real-time clock, performing mathematics, taking sonar ranges, etc.

After you get your "want list" together, you can start searching for a computer that will meet all your needs. Often, you will find that a suitable computer does not exist. This leaves you with three choices: make do with what is available, give up the project as a lost cause, or build a custom computer.

That's the situation in which we found ouselves when we started designing our GEMINI robot. We had a detailed list but no vendor. After careful consideration, we decided to build our own computer.

We wanted GEMINI's main computer to be a general-purpose process control computer that would be equally at home driving GEMINI, the wave flaps for our sister company's waterpark wave makers, as well as someone else's homebrew robot.

This article describes the features we built into this computer and provides the complete construction plans.

SPECIFICATIONS
The first step when designing a computer for your robot is making a detailed list of desired hardware and software features. This may not be much fun, but it is probably the most important step in the project and you

A Low-Power, General-Purpose Computer for Your Robot

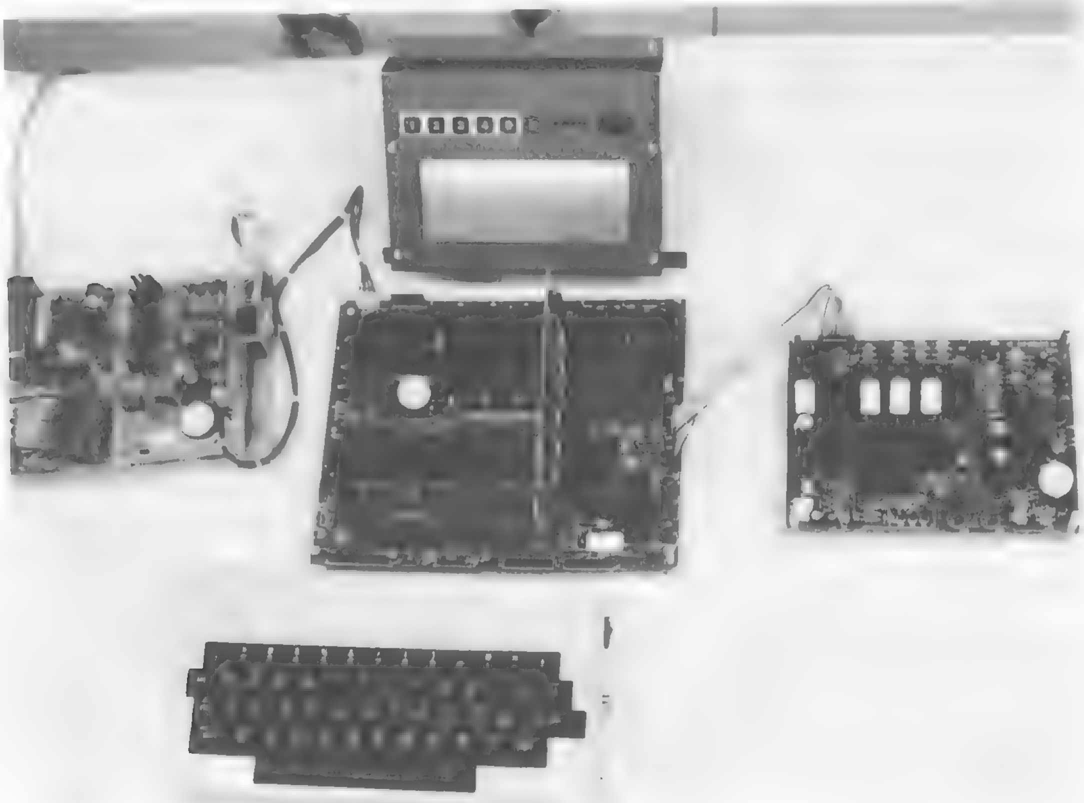
Jack W. Lewis
Michael W. Fowler
Arctec Systems
9103 Red Branch Rd.
Columbia, MD 21045

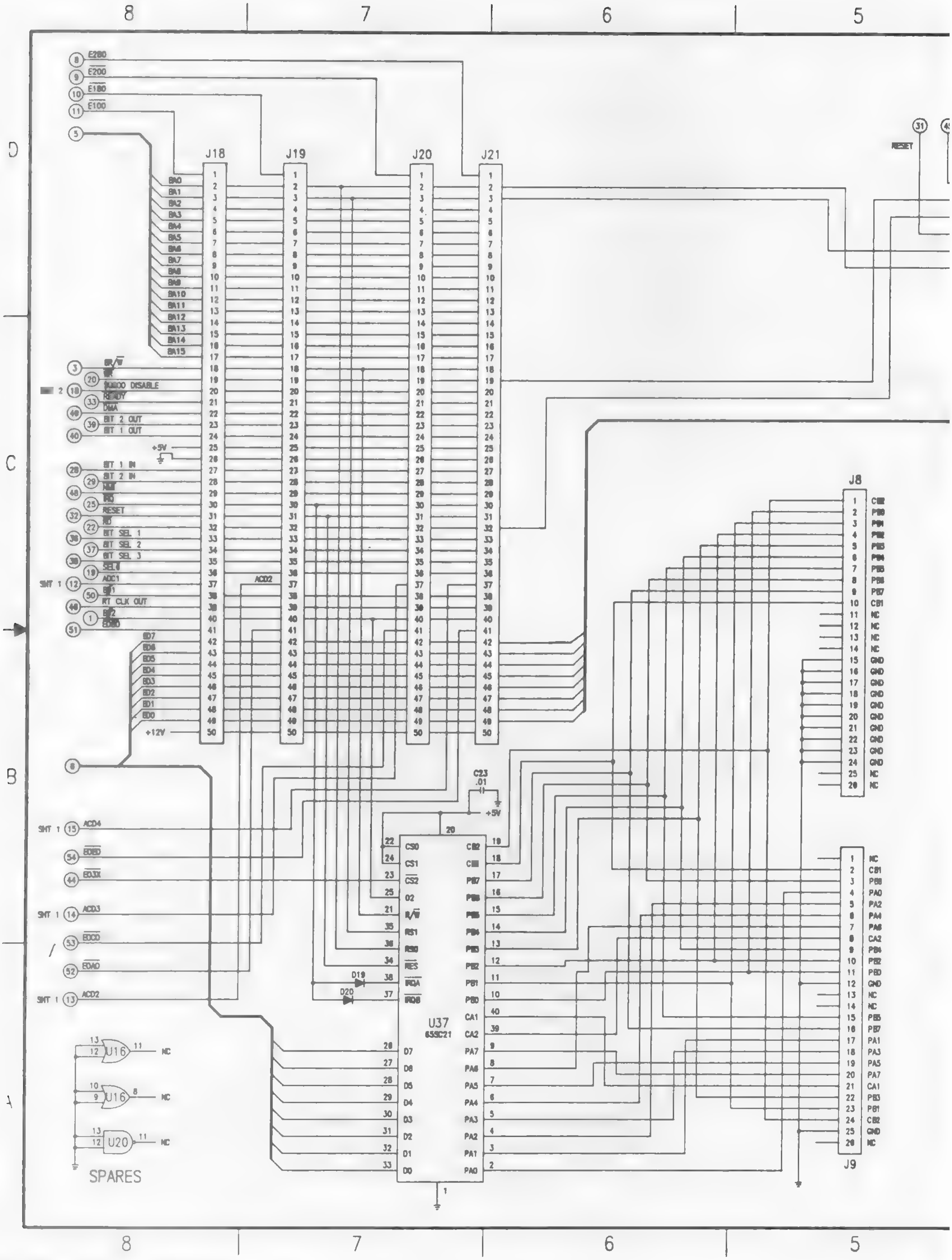
should not treat it lightly. Ask yourself many questions starting with general ones like, "What are the principal functions I want this computer to perform?" Then go on to more specific questions like, "How many bit inputs do I need and how will they be used?" It helps to have other designs available so you can see how someone else did it. That way, you can build upon the expertise and experience of other designers.

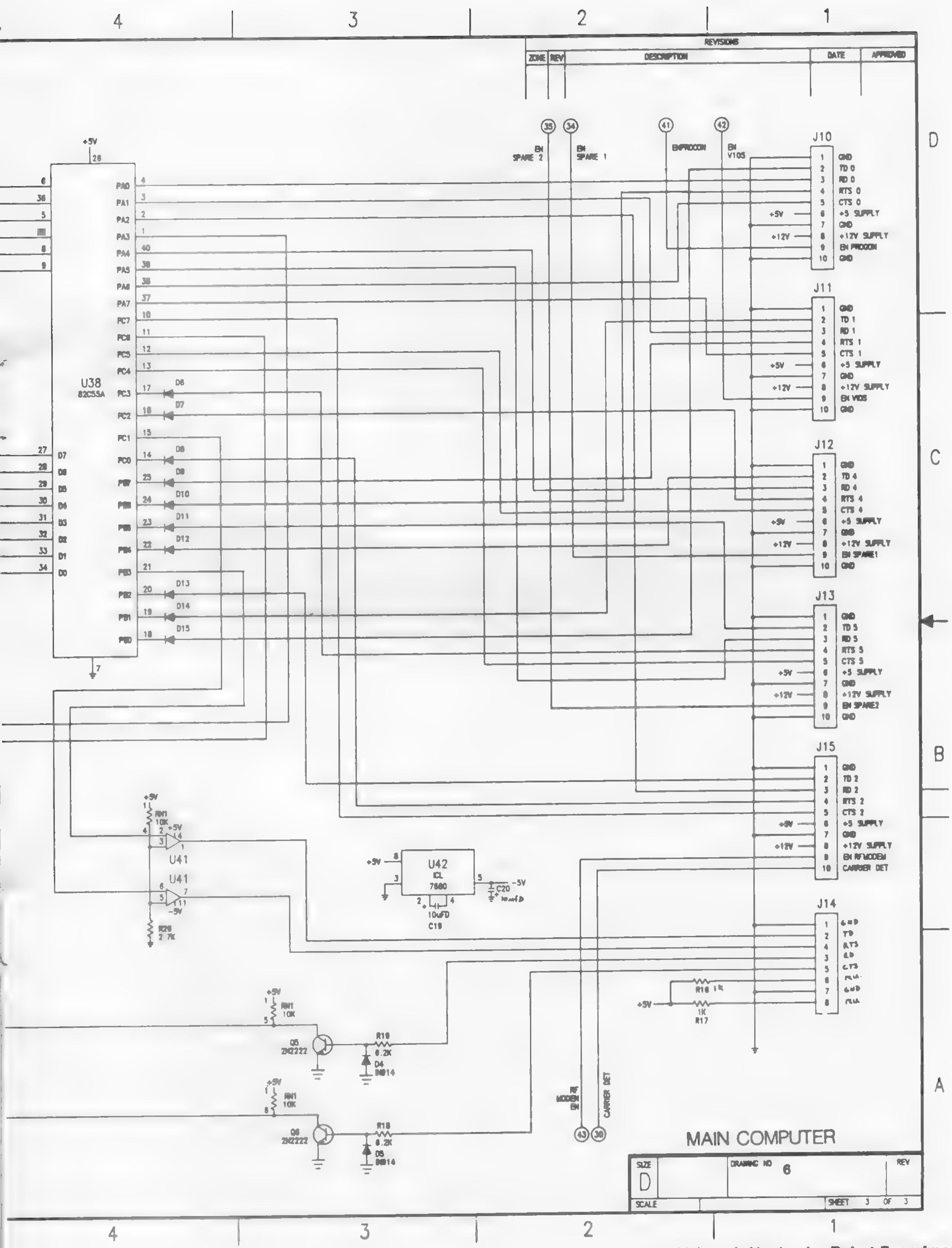
Table 1 lists most of the design specifications we developed for GEMINI's main computer. We attempted to minimize power consumption wherever possible. Why is this so important? Power consumption dictates the size of batteries required for a given number of off-charger hours of operation. Batteries are heavy and the heavier the robot, the more power required to move it around. This in turn means larger batteries, which weigh more, and you find yourself in a vicious circle.

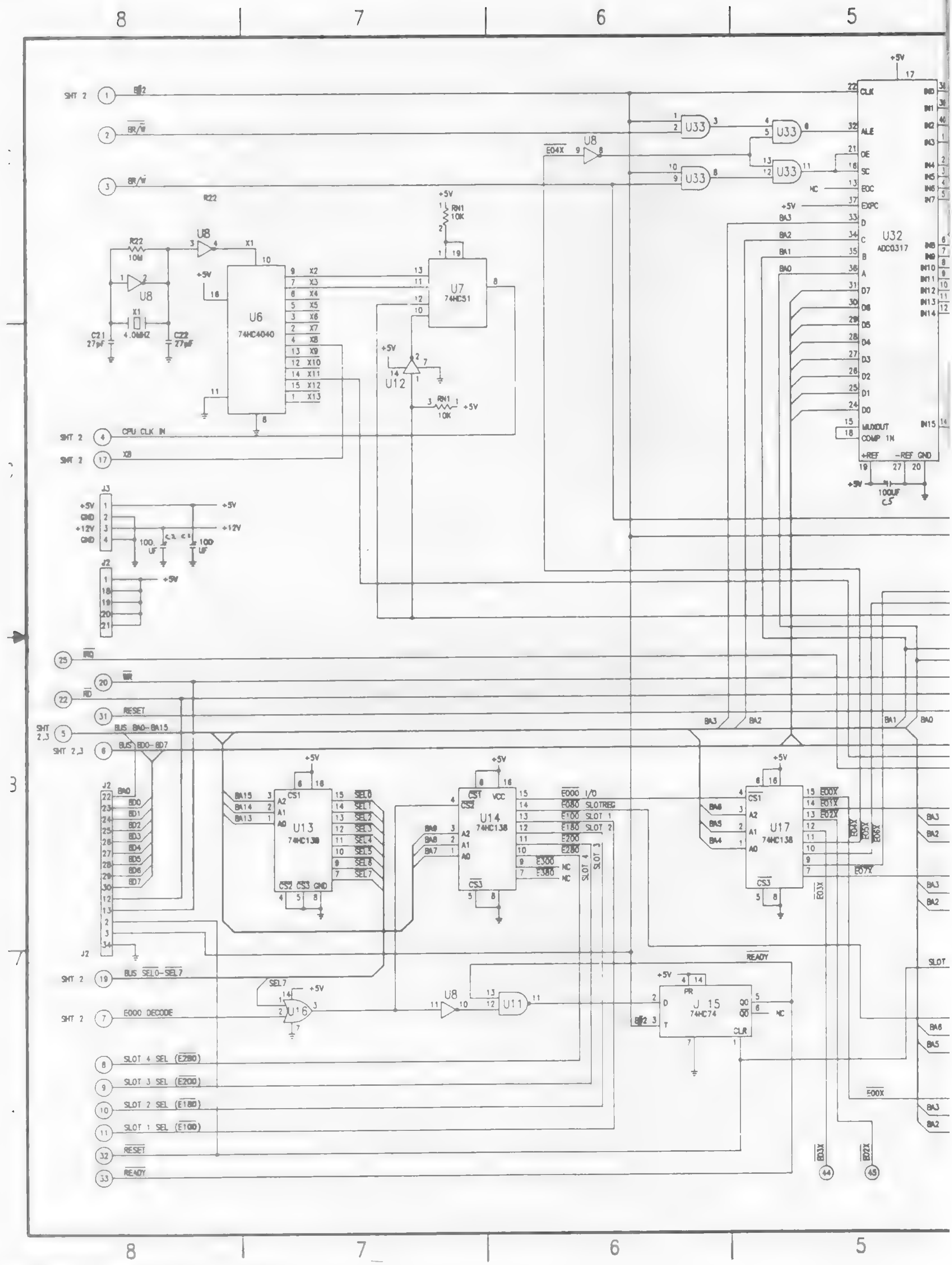
We selected the Rockwell 65C02 CMOS microprocessor because the first generation NMOS 6502 was very popular and their is a lot of software and design books available for this machine. The CMOS version consumes only 4mA of current compared to 90mA for the NMOS version running at 1 MHz.

The CMOS 65C02 also has an enhanced instruction set that allows you to write more compact (hence faster) code. We selected the Rockwell version over the GTE or NCR versions because the Rockwell has a more highly expanded instruction set.

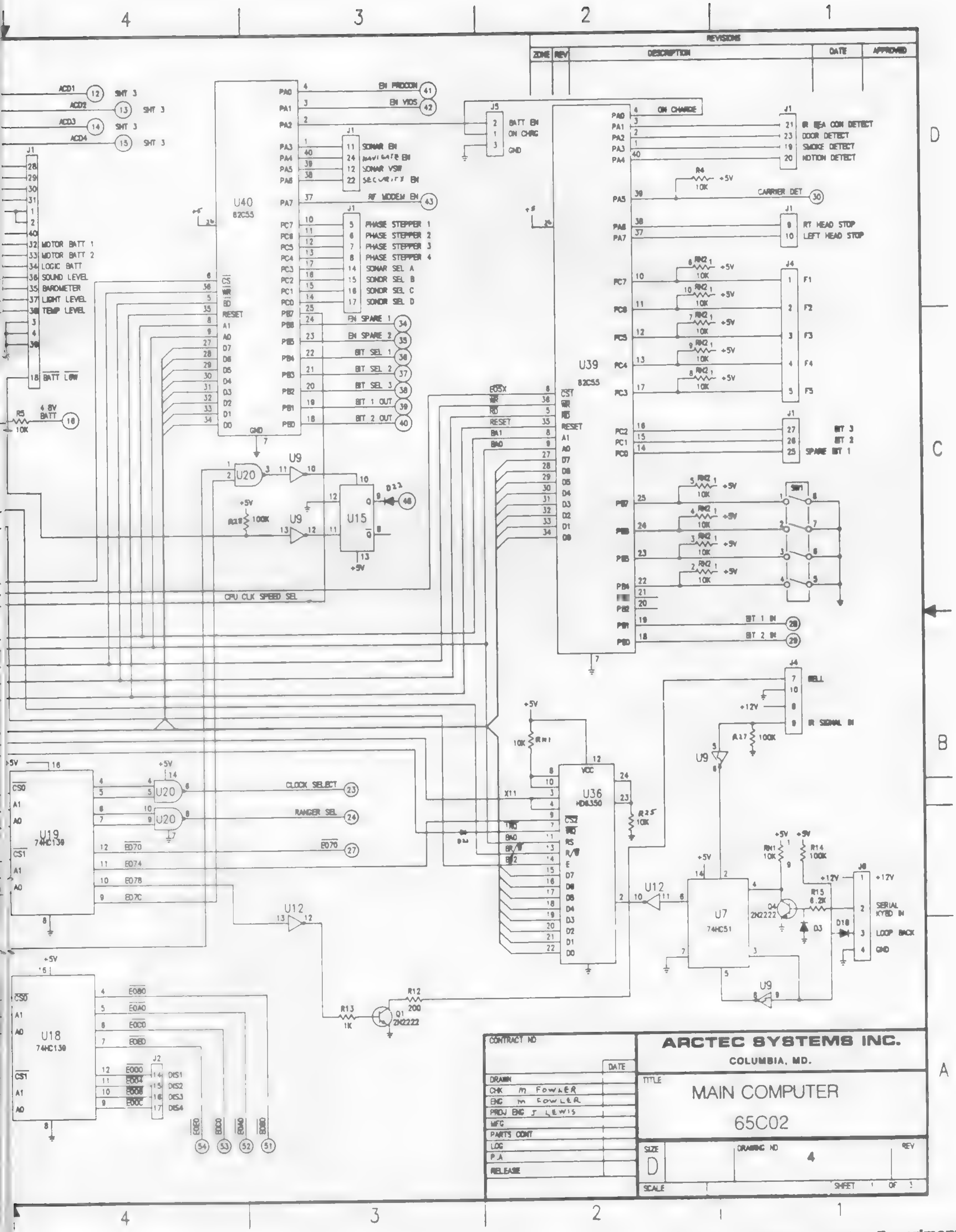


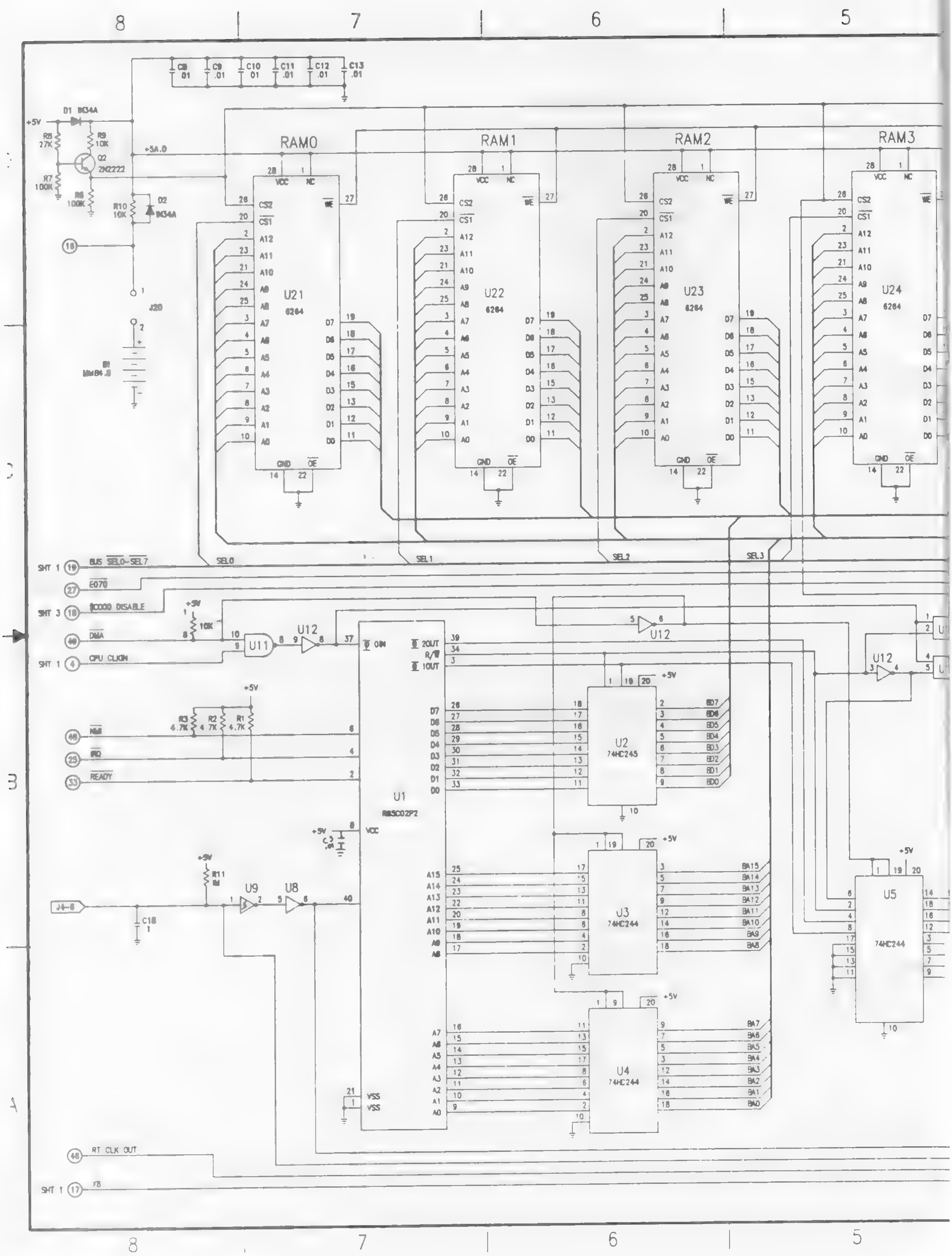

J18
J19
J20
J21
J8
J9
U37
65SC21
C23
.01
+5V
+12V
U16
U20
SPARES
RESET
ADC1
ADC2
ADC3
ADC4
BIT 1 OUT
BIT 2 OUT
BIT 1 IN
BIT 2 IN
BIT SEL 1
BIT SEL 2
BIT SEL 3
RT CLK OUT
D19
D20

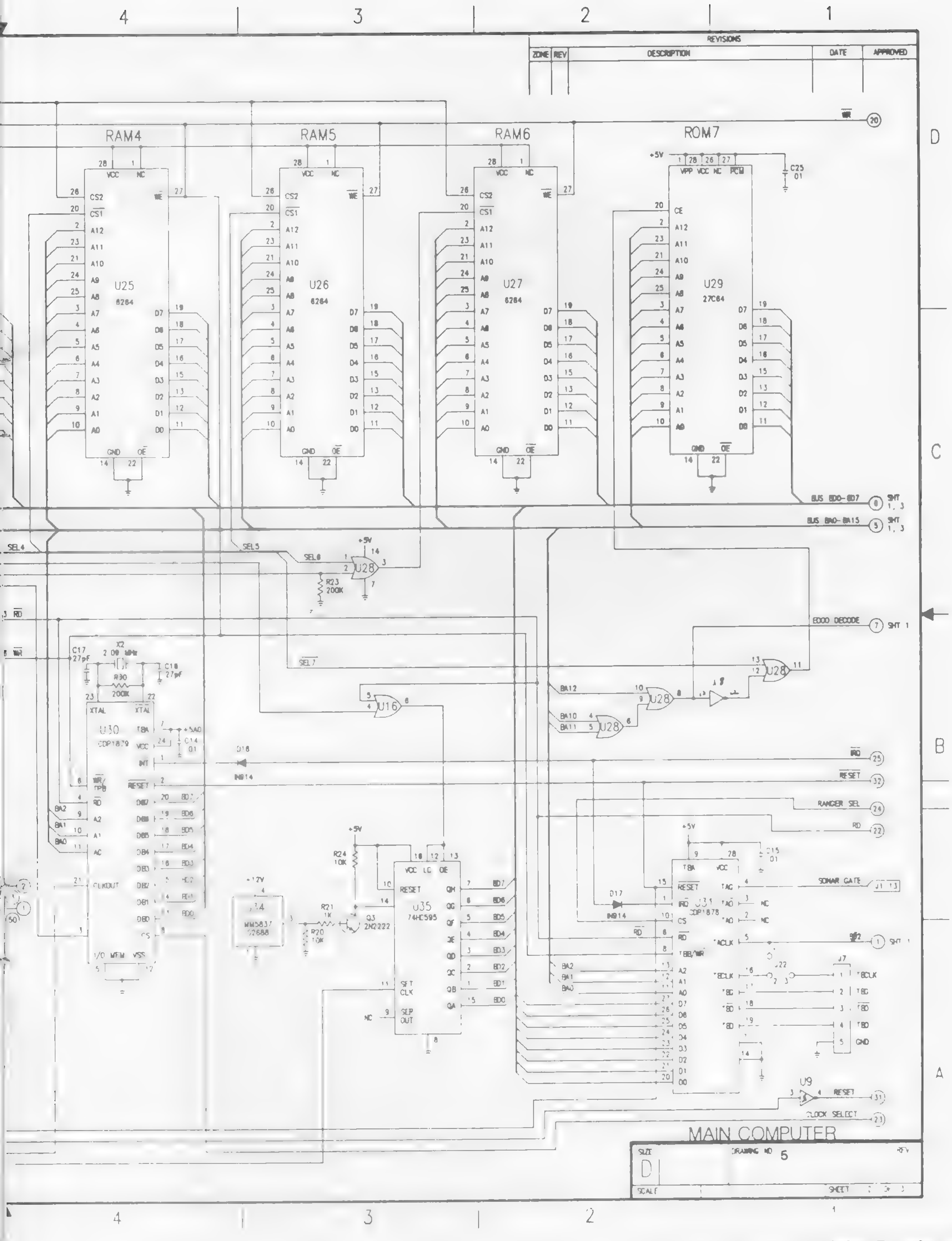

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
U38
82C55A
U41
U42
ICL
7660
J10
1 GND
2 TD 0
3 RD 0
4 RTS 0
5 CTS 0
6 +5 SUPPLY
7 GND
8 +12V SUPPLY
9 EN PROCOM
10 GND
J11
1 GND
2 TD 1
3 RD 1
4 RTS 1
5 CTS 1
6 +5 SUPPLY
7 GND
8 +12V SUPPLY
9 EN V105
10 GND
J12
1 GND
2 TD 4
3 RD 4
4 RTS 4
5 CTS 4
6 +5 SUPPLY
7 GND
8 +12V SUPPLY
9 EN SPARE1
10 GND
J13
1 GND
2 TD 5
3 RD 5
4 RTS 5
5 CTS 5
6 +5 SUPPLY
7 GND
8 +12V SUPPLY
9 EN SPARE2
10 GND
J15
1 GND
2 TD 2
3 RD 2
4 RTS 2
5 CTS 2
6 +5 SUPPLY
7 GND
8 +12V SUPPLY
9 EN RFMODEM
10 CARRIER DET
J14
EN SPARE 2
EN SPARE 1
ENPROCOM
EN V105
RF MODEM EN
CARRIER DET
Q5 2N2222
Q6 2N2222
MAIN COMPUTER
SIZE D
DRAWING NO 6
REV
SCALE
SHEET 3 OF 3



U6
74HC4040
U7
74HC51
U8
U12
U13
74HC138
U14
74HC138
U17
74HC138
U32
ADC0317
U33
U11
U16
J 15
74HC74
CPU CLK IN
BUS BA0-BA15
BUS BD0-BD7
BUS SEL0-SEL7
E000 DECODE
SLOT 4 SEL (E280)
SLOT 3 SEL (E200)
SLOT 2 SEL (E180)
SLOT 1 SEL (E100)
RESET
READY


ARCTEC SYSTEMS INC.
COLUMBIA, MD.
MAIN COMPUTER
65C02
CONTRACT NO
DRAWN
CHK M FOWLER
ENG M FOWLER
PROJ ENG J LEWIS
MFG
PARTS CONT
LOG
P.A
RELEASE
SIZE D
DRAWING NO 4
SCALE
SHEET 1 OF 3
REVISIONS
ZONE REV DESCRIPTION DATE APPROVED
U40 82C55
U39 82C55
U36 HD6350
U19 74HC139
U18 74HC139
U7 74HC51
U15
CPU CLK SPEED SEL
CLOCK SELECT
RANGER SEL


RAM0
RAM1
RAM2
RAM3
U21
U22
U23
U24
6264
U1
R65C02P2
U2
74HC245
U3
74HC244
U4
74HC244
U5
74HC244
U11
U12
U9
U8
D1 1N34A
D2 1N34A
Q2 2N2222
+5A.0
J20
B1
BUS SEL0-SEL7
E070
$C000 DISABLE
DMA
CPU CLOCK
NMI
IRQ
READY
RT CLK OUT
SEL0
SEL1
SEL2
SEL3
SHT 1
SHT 3
J4-6
C18
R11


RAM4
RAM5
RAM6
ROM7
U25
6264
U26
6264
U27
6264
U29
27C64
BUS BD0-BD7
BUS BA0-BA15
E000 DECODE
U28
U16
U30
CDP1879
U35
74HC595
U31
CDP1878
MM5837
2N2222
IRQ
RESET
RANGER SEL
RD
SONAR GATE
CLOCK SELECT
MAIN COMPUTER
DRAWING NO 5

The 65C02 is available in 1, 2, 3, or 4 MHz versions. We used the 2 MHz version and developed a scheme that allows us to alter the clock speed under program control. This saves power in operations such as wait loops (the 65C02 consumes 4 mA at 1 MHz) and still allows high-speed computations (the 65C02 consumes 8 mA at 2 MHz).

The 64 Kbytes of directly addressable memory space was split into 56 Kbytes of user-programmable memory (RAM), 1 Kbytes of input/output (I/O) space, and 7 Kbytes of read-only memory (ROM) space. This provides lots of room for powerful ROM-based monitor software, ample room for I/O devices, and plenty of room for user-developed programs. We also provided the capability to bankswitch another 56 Kbytes of memory (RAM or ROM) into one of the 8 Kbyte RAM memory locations. We also selected static in lieu of dynamic programmable memory so it could be battery backed.

Table 1. Robot computer design specifications.

HARDWARE:

Microprocessor	- Rockwell 65C02 CMOS operation at 1 and 2 MHz
Programmable Memory	- 56 Kbytes of battery-backed static CMOS memory in 8 Kbyte packages
Read-only Memory	- 7 Kbytes onboard for monitor program
Input/Output	- 1 Kbytes for all I/O functions
Bank RAM/ROM	- 56 Kbytes of bank switchable RAM or ROM
Character Display	- Capable of driving an 8 line by 40 character LCD display
Clock	- Real-time clock with alarm interrupt capabilities
Counter/Timer	- Two 16-bit counter-timers
Serial Ports	- Six serial ports. One configured as RS-232C
Parallel Ports	- Two 8-bit wide I/O ports with handshaking lines. One configured as a Centronics printer port
A/D Converter	- One 16-channel, 8-bit CMOS analog-to-digital converter with less than 100 microsecond conversion time
Bit Input	- 24 digital input lines
Bit Output	- 24 digital output lines
Random Numbers	- Hardware generated
Character Input	- Capable of receiving ASCII characters serially from a terminal or smart keyboard
Bell	- Piezoelectric buzzer
Buffer	- All address, data, and control lines fully buffered
DMA	- Supports direct memory access
Expansion	- Four 50-pin connectors closely matching Apple II pinouts
Logic Family	- High-speed CMOS wherever possible

SOFTWARE

MONITOR COMMAND LANGUAGE:
- Single-letter commands to set and read the real-time clock, send and receive data on the dual parallel port, send and receive data on the RS-232C serial port, send output to a printer, enter bank RAM/ROM programs, and enter user programs.
- Single address commands to run a user program, disassemble code, display memory locations, and alter memory.
- Multiple address commands to output a range of memory to current output device, fill a range of memory with a given hexadecimal character, move a range of memory, and verify a range of memory.

UTILITIES
- Character output support for vectored character output. Separate LCD routines to support scrolling, etc.
- Auxiliary computer character I/O with separate input/output routines for each serial port with polling.
- Stepper motor driver routines to initialize a stepper motor, take one step, and take multiple steps.
- Sonar ranging routines to multiplex up to 10 sonars and take ranges on each.
- Processor speed selection routines to switch between 1 and 2 MHz
- Bank switching routines to handle bank-to-bank subroutine calls, jumps, fetching memory contents, and saving memory contents between banks
- Math pack provides 24-bit signed fractional integer math pack with trigonometric capabilities.

Noteworthy Products

INTERFACE ACQUIRES BOARDS

Interface Technology, Inc. has acquired the rights to Micromation's line of products for the HERO-1 robot and will rerelease these products to the hobby and educational community. This includes the MEMCOM board, the VOREC voice recognition board, the Apple-HERO communicator, and the line of Apple computer-based software for the Hero.

Initial prices will remain unchanged, but will be reviewed in the light of component price decreases. Interface also plans to release bare board and kit versions of the products. Circle 19

For more information, contact: Patrick Stakem, Interface Technology, Inc., PO Box 3040, Laurel, MD 20708, 301/490-3608.

Lisp for IBM-PC

UO-LISP is now available on the IBM-PC and compatibles. For professional programmers, engineers, researchers, and educators, UO-LISP maintains the power and flexibility inherent in Lisp while providing the expected functionality of mainframe Lisp systems.

The UO-Lisp interpretive kernal contains over 200 standard Lisp functions. Precompiled library packages expand the system to over 400 functions. All functions are user redefinable. Map functions, property lists, vectors, read and print macros, automatic garbarge collection, operating system access, and I/O support are standard. UO-LISP also provides an optimizing compiler that generates 8086 code providing execution speeds many times faster than intrepretive systems.

The system comes complete with a 300 page reference manual and over 30 packages including those associated with compiling, debugging, program development, extended arithmentic, document processing, a higher-level language, translator writing, and editing.

UO-LISP Version 3 requires an IBM-PC or compatible with a minimum of 128 Kbytes of memory, two DSDD 320 Kbyte disk drives, PC-DOS 1.1 or higher or MS-DOS 2.0 or higher. UO-LISP V3.0 has an introductory price of $150. An associated Learn Lisp System costs $85. UO-LISP for CP/M computers is still supported.

Contact Northwest Computer Algorithms, PO Box 90995, Long Beach, CA 90809, 213/426-1893 for detailed brochures. Circle 20

In order to save power, we choose to limit display information to a 40 character by 8 line alphanumeric liquid crystal display (LCD). The unit we selected draws 5 mA of current and operates off a single +5 V power supply.

We designed a real-time clock on board so the robot could tell time and set alarms to remind itself of tasks to be performed.

At least one 16-bit counter/timer was needed for sonar ranging. The chip we selected has two such counter/timers. (Sonar ranging is performed by emitting an ultrasonic chirp and then counting how long it takes for the sound to return. The amount of time it takes for the chirp to return, divided by the speed of sound, gives you the distance to the object off of which the sound bounced.)

Six serial communications ports were desired so we could have the computer control up to six auxiliary computers. One of these ports is configured as standard RS-232C so the computer can communicate with RS-232C devices such as terminals and other computers.

We also wanted a dual, 8-bit wide parallel port with handshaking lines in order to allow high-speed data transfer with our program development computers. Most of our software was developed on the Apple II series computers for which we had specially designed a card to transfer programs to/from the robot computer. We also had a similar card for the IBM PC. One side of the dual 8-bit parallel port is configured to output characters to a printer.

At least eight analog-to-digital (A/D) converter channels were needed for our planned GEMINI application. We ended up with 16. We made one channel available to each of the four on-board expansion slots and left the other four for future expansion. We also wanted fairly fast conversion times so we selected a converter with a 60 microsecond conversion rate that was available in low-power CMOS.

We elected to have 24 bit input and 24 bit output lines in order to make spares available for experimenters and to handle all the digital I/O needed on GEMINI. One chip conveniently handles this number of bits.

The computer also contains a hardware random number generator since many artificial intelligence (AI) programs use random numbers during their operation. We felt that using keyboard wait routines for generating such numbers (the method used by Apple II and similar computers) was not feasible.

We also wanted keyboard communications to be handled serially by either a smart keyboard or a separate terminal using ASCII serial data. We included a bell to alert users of errors, key presses, and for use by the robot to signal alarm conditions.

All address, data, and control lines are buffered in order to provide maximum driving capabilities for the expansion slots and to support direct memory access (DMA) functions such as disk drives or vision systems.

The computer has four on-board expansion slots for future use. One of these slots is used on GEMINI for the RAM/ROM Expansion Card and contains all the high level software on that robot. Another is used for the controller card for a tape or disk drive. The expansion slots are patterned after those on the Apple II-series computers. This makes many Apple II peripherals available for the robot computer.

To conserve power and allow high-speed operation, the new high-speed 74HCxx CMOS logic family is used wherever possible. Although this logic family currently costs more than the LSTTL family (74LSxx), this choice helped make the entire computer, fully loaded and running at 2 MHz, consume only 90 mA. Such a feat could not have been accomplished using the LSTTL logic family.

The software specifications are fairly self-explanatory. We wanted to cram as much useful software as possible into 7 Kbytes of memory space. Driver routines for every I/O device on the computer are in the monitor. We didn't want users to have to write their own drivers. We also wanted to include as much debugging software as possible.

HARDWARE DESIGN

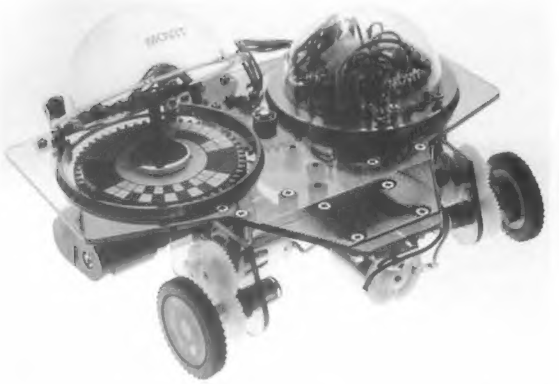
Photo 1 shows the main computer along with a power supply, the liquid crystal display, our smart keyboard, the RAM/ROM expansion card, a sonar/signal conditioner/stepper motor board (SSS Board) and an auxiliary computer. This photo gives you a feel for the ease with which boards are connected to the robot computer. Figure 1 provides a full schematic diagram for the computer.

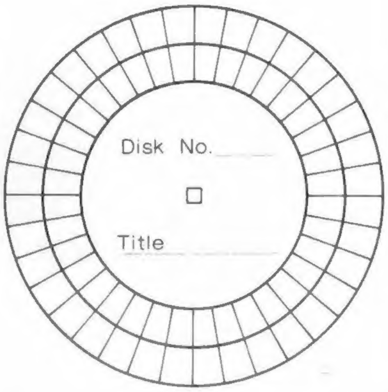
NEXT MONTH

Part II of this article, continued next month, provides a thorough description of the I/O system and software that was designed into the system. If you will send Arctec Systems a photograph of your completed board, they will send you a commented source listing of their system monitor for your personal use, free of charge.

The OWI Navius

Staff





Occasionally, you find a product that provides so much enjoyment that you feel compelled to tell everyone you meet about it. The Movit robots are one such product line. The Movits, from OWI, are "robots" that run, skip, and walk around the room, respond to sounds and light, avoid objects in their paths, or read simple left/right program commands from programmable diskettes. Each machine in the product series exhibits one or more of the above functions.

We recently enjoyed assembling the OWI Navius kit, (Photo). According to the documentation, the term Navius is a contraction of the terms Navigate and Mevius. Unfortunately, the documentation does not define Mevius but does state that Navius has, "a cosmic word feeling."

Taken at its simplest, Navius is an old-fashioned, intelligent traffic-light controller. Navius is programmable and takes its commands from a slowly rotating paper disk. This disk (Figure) is divided into two concentric, partitioned rings. You program the Navius by darkening selected sectors with a good quality (H or HB) pencil. The outside ring controls the left drive motor, the inside ring controls the right. The control algorithm is simplicity itself. When the Navius' twin infrared detectors find a black surface, the corresponding motor activates. Thus, to turn right, darken the outside circle to activate the left motor and vice versa. To move forward, blacken both rings. The prepared paper disk is then placed on a large gear and the gear is placed inside one of the Navius' two domes. When the dome is closed and the on/off switch activated, the program disk spins and the Navius heads off on its assigned rounds.

ASSEMBLY. The OWI assembly manual is well arranged and illustrated. Although the manual was obviously written and translated in Japan, the lapses into poorly-translated English are minor inconveniences. Though the English was occasionally obtuse, the detailed illustrations were never confusing and answered all our questions.

The only difficulty we had while constructing the Navius robot was the gear-train that drives the progam gear. Although it would work well in partial-assembly tests, it would jam once all the screws were tightened down. After playing around with it for awhile, we ascertained the problem was solved by applying some grease (supplied with the kit) to the gear mounts. Since then, the kit has performed admirably.

CONCLUSION. The Navius kit took one person approximately four hours to assemble. From talking to other people who build Movit kits all the time, this is a typical time and can be shortened if you build a lot of kits.

Although these ingenious little devices really aren't robots, they do provide a lot of fun and instruction on mechanical details. OWI, Inc. can be reached at 1160 Mahalo Place, Compton, CA 90220, telephone 213/638-4732. The kits are available at many computer and hobby shops.

An Affordable Robot Arm

Tim Knight
410 Sheridan Ave., #106
Palo Alto, CA 94306

I've wanted a computer-controllable robot arm ever since I got my first computer nearly six years past. Unfortunately, until a few months ago, you could expect to pay at least $1200 for a small robot arm.

Recently, fishertechnik, a large German toy and hobby products manufacturer, introduced a robot arm that costs only $199 and can also be made into nine other forms (Photo 1). The robot arm can be connected to a computer and is compatible with a wide variety of available fishertechnik electronics, motors, gears, and accessories.

The robot arm kit can be connected to the Commodore 64, VIC-20, and Apple II-series computers. An IBM PC-compatible kit will soon be introduced. These kits are intended for educational purposes, but they can also be a lot of fun for computer and robot experimenter interested in seeing just what can be accomplished with a kit of this type.

The BASIC programs included in the fishertechnik software disk make the learning process easier, while the flexible kit challenges you to construct the hardware for each product. Although specific assembly instructions are included, some of the projects (like the arm itself) can take up to four hours. After constructing these projects, you will have a very good basic understanding of these mechanical projects.

The fishertechnik kit's two 3 VDC motors, two gears, electromagnet, three lamps, eight push-buttons, two potentiometers, and computer input/output (I/O) connector are accompanied with instructions for building the following ten projects:
Robot Arm: The arm can move left, right, up, and down and uses an electromagnet to pick up small metallic objects.
Traffic Light: A simple light operated from a pedestrian crossing button introduces basic input and output principles with an understandable "real life" model.
Machine Tool: This workstation feeds and processes materials on a very small scale.
Materials Lift: An elevator moves between floors and deals with priority and stored calls for each level.
Aerial Rotor: A pulse-modulated rotor designed to rotate to a precise location.
Sorting System: This project sorts objects based on their length.

Photo 1: The fishertechnik $199 robot arm can be connected to a variety of personal computer systems.

Towers of Hanoi: This project lets your computer struggle with this ancient puzzle. The robot arm moves the small disks to solve the puzzle.
Graphic Panel: A simple plotter-type device that lets you exchange the drawing board for the computer screen.
Plotter: This more sophisticated plotter lets your computer draw using polar coordinates.
Solar Cell Tracking: This device remains constantly aimed at the sun or any other bright, moving object.

For its price, this product is absolutely phenomenal and should really get a lot of dusty computers out of the closet. It's educational, a lot of fun, and, perhaps most importantly, will get a lot of children and adults interested in robots at a low price. More exciting is the fact that fishertechnik plans to introduce an even more sophisticated arm later this year.

For more information about the fishertechnik robot arm, contact fisher America, Inc. 175 Route 46 West, Fairfield, NJ 07006, telephone 201/227-9283.

The fishertechnik arms are also available from a variety of dealers, including: Robot Center of San Jose California (408) 255-2331; Rio Grande Robotics of Los Cruces New Mexico (505-524-9480; Creative Learning Systems of San Diego California (714) 231-3599; and many other robot and specialty shops.